TITLE LINE 1
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A THESIS

submitted by

SHASHANK SINGH
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TIRUCHIRAPPALLI – 620015

MAY 2019

To My Beloved Family

THESIS CERTIFICATE

This is to certify that the thesis entitled **TITLE OF THESIS** submitted by **Name of Student** to the National Institute of Technology, Tiruchirappalli for the award of the degree of **Master of Science (By Research)** is a bonafide record of research work carried out by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Tiruchirappalli – 620015.

Date: 10–05–2019

Name of Guide

Research Supervisor &
Associate Professor,
Electrical & Electronics Engineering,
National Institute of Technology,
Tiruchirappalli – 620015, India.

ABSTRACT

Smart Grid (SG) is a paradigm where the information and communication technology fuses with the legacy electrical power grid. Bestowing a bi–directional communication interface between the consumer and the electric utility, Advanced Metering Infrastructure (AMI), an innovative constituent of SG, bridges the gap. Thereby, consumers may respond to incentive–based schemes, such as dynamic constraint on power consumption and dynamic pricing. These parameters can be referred to as key–utility parameters, which could provide significant savings on a consumer's electricity bill for a consumption pattern.

Keywords**:** Advanced Metering Infrastructure; Communication Infrastructure; Demand Response; Electric Vehicle Charging; Energy Management; Load Management; Microcontrollers; Multi–Agent System; Smart Grid; Smart Metering; Thermostatically Controlled Loads.

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SHASHANK SINGH

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NOMENCLATURE

$I_{max}^{charging}$	Maximum value of EV charging current
P_{AC}	AC power consumption
S	Status vector of a SL
Ψ	Duration of one scheduling interval
χ	Preemptive status of a SL
δ	Transition state in SWNA
$\mathscr{L}$	Set of SLs
$\mathscr{T}$	Set of scheduling intervals
ϖ	Stop time of a SL
ϑ	Start time of a SL
ζ	Run time of a SL

ABBREVIATION

AI	Artificial Intelligence
DLC	Direct Load Control
DR	Demand Response
DSM	Demand Side Management
HEMS	Home Energy Management Sytem
ICT	Information and Communication Technology
IoT	Internet of Things
MAS	Multi–Agent System
MDL	Maximum Demand Limit
RTP	Real Time Pricing
SG	Smart Grid
ToU	Time of Use

CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

Electrical power system is one of the most complex and critical technical innovations of mankind. A legacy power system hosts generation, transmission, distribution, and consumption infrastructure, wherein large power plants pump power into the grid and try to keep a balance between generation and demand at all times.

The Smart Grid (SG) is a melting point of an evolving set of various technologies, especially information and communication technologies (ICT), computational intelligence, and sophisticated control algorithms working together to improve the existing grid. Numerous reputed organizations are working towards the development of SG, and have come up with their definitions, a few of which are listed herein:

U.S. Department of Energy: “Grid 2030 envisions a fully automated power delivery network that monitors and controls every customer and node, ensuring a two–way flow of information and electricity between the power plant and the appliance, and all points in between” [Borlase (2016)].

Indian Electricity Act 2003 – Amendment Act 2018 (Draft) (61A): “Smart Grid means an electricity network that uses information and communication technology to gather information and act intelligently in automated manner to improve the efficiency, reliability, economics, and sustainability of generation, transmission and distribution of electricity as may be specified by the Authority” [Ministry of Power (2018)].

The SG may be regarded as an intelligent grid, an upgrade to the 20th and early decade 21st century grid. In contrast, SG provides pervasive control, self–monitoring, self–healing, adaptive and islanding features, enables two–way flow of information alongside electricity, distributed generation, energy trading, and enhances consumer participation [Fang *et al.* (2012)]. The SG and its underlying key actors have been conceptualized by the National Institute of Standards and Technology, U.S. Department of Commerce, which are depicted in Fig. 1.1.

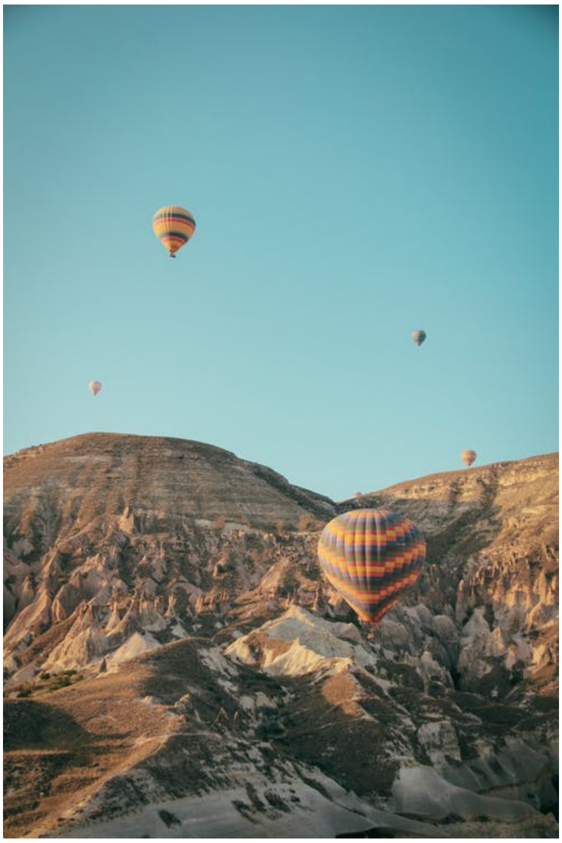

Fig. 1.1 Sample Image

1.2 LITERATURE REVIEW

1.2.1 Constituents of Advanced Metering Infrastructure

Paragraph text goes here.

A. ***Advanced Metering Infrastructure***

Advanced metering infrastructure (AMI) is an integrated system of smart energy meters (SEM), communication networks, and meter data management systems (MDMS) that enables bidirectional communication between utilities and consumers [Park *et al.* (2010)].

B. ***Load Monitoring in AMI***

Paragraph text goes here.

1.3 OBJECTIVE AND SCOPE OF THE PRESENT RESEARCH WORK

The objectives of the present research work are as follows:

1. First Novel Point

    - supportive statements;
    - benefits;
2. Second Novel Point
    - supportive statements;
    - benefits;

The scope of the present research work adopts a steady state modeling of household appliances from [Arun and Selvan (2017)]. Replace existing sample paragraphs with your paragraphs.

1.4 ORGANIZATION OF THESIS

Chapter 2: This chapter deals with.

Chapter 3: In this chapter.

CHAPTER 2

CHAPTER 2 NAME GOES HERE

2.1 INTRODUCTION

Paragraph text goes here.

2.2 SAMPLE EQUATION ARRAY

Use align syntax for equation array. Sample has been given below:

$$S_l = [s_l^1, s_l^2, ..., s_l^t, ..., s_l^M] \quad \forall\, l \in \mathscr{L} \tag{2.1}$$

$$s_l^t = \begin{cases} 0 & \text{if } l^{th} \text{ SL is OFF} \\ 1 & \text{if } l^{th} \text{ SL is ON} \end{cases} \quad \forall\, l \in \mathscr{L} \tag{2.2}$$

$$\zeta_l \leq \varpi_l - \vartheta_l \quad \forall\, l \in \mathscr{L} \tag{2.3}$$

$$\chi_l = \begin{cases} 0 & \text{for ISL} \\ 1 & \text{for NISL} \end{cases} \tag{2.4}$$

$$P_{SL} = \sum_{t=1}^{M} \sum_{l=1}^{N} (s_l^t . P_l) \tag{2.5}$$

Similarly, sample table is given below:

Table 2.1 Internal parameters of battery during discharging

SoC	$R_0\ (m\Omega)$	$R_1\ (m\Omega)$	$C_1\ (kF)$	$R_2\ (m\Omega)$	$C_2\ (kF)$
0	118.152	23.49	0.447601	2.328	2.306946
10	116.176	09.81	0.377278	1.417	1.430313
20	116.176	14.19	0.340939	1.982	1.886134
30	110.702	10.84	0.388916	5.174	0.772787
40	114.272	06.23	0.319658	3.128	0.677029
50	112.429	03.51	0.838898	3.371	0.932269
60	105.512	05.64	0.514280	3.923	0.753494
70	107.239	04.64	0.854056	1.184	2.098372
80	105.615	06.16	0.503514	1.885	2.638010
90	105.512	06.33	0.434482	1.418	1.766140
100	099.014	17.08	0.417306	4.515	0.965072

CHAPTER 3

CHAPTER NAME GOES HERE

3.1 INTRODUCTION

DR programs are a portfolio of signaling schemes from the utility to consumers for load shifting/shedding with a given deadline.

3.2 SAMPLE ALGORITHM

Furthermore, the pseudocode depicted in algorithm 3.1 explicitly describes the underlying load prioritization subroutine.

Algorithm 3.1 Load Prioritization Subroutine

```
P_R^t = MDL − P^t                                           ▷ Remaining power
j = 1                                                       ▷ iterator
X = [i_1, i_2, i_3, ........, i_N]                          ▷ load numbers
Y = [h_1^t, h_2^t, h_3^t, ........, h_N^t]                  ▷ load priority array
Z = [{X(1) : Y(1)}, {X(2) : Y(2)}, ........., {X(N) : Y(N)}] ▷ {key:value} pair
z = [sorted(Z{key : value})]                                ▷ descending order of value
for j in range 1 → length(z) do
    if P_{z[j]} > P_R then
        H[z{j}] ← 0
    else
        H[z{j}] ← 1
    end if
    end
    P_R^t ← P_R^t − P_{z[j]}
end for
end
for k in range 1 → length(H) do
    if H(k) == 1 then
        load status = ON
    else
        load status = OFF
    end if
    end
end for
end
```

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LIST OF PAPERS BASED ON THE THESIS

Patent Filed

1. **Singh, S.**, **A. Roy** and **M. P. Selvan** Smart Load Node System for Operating an Appliance and Method Thereof. *Intellectual Property India Journal*, March 01, 2019, App No. 201741039083 dated November 2, 2017.

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1. **Singh, S.**, **A. Roy** and **M. P. Selvan** (2019) Smart load node for nonsmart load under smart grid paradigm: a new home energy management system. *IEEE Consumer Electronics Magazine*, **8**(2), 22–27.

International Conferences

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2. **Singh, S.** and **M. P. Selvan** (2019) A smart energy meter enabling self-demand response of consumers in smart cities of Tamil Nadu. *International Conference on Smart Cities Model (ICSCM 2019)*, IIT Madras, Chennai, India.

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Papers Under Review

1. **Singh, S.**, **S. Thirumalai** and **M. P. Selvan** Realization of self-demand response through non-intrusive load monitoring algorithm. *IEEE CONECCT 2019*, IIIT Bangalore.

CURRICULUM VITAE

SHASHANK SINGH

`DoB: October 01, 1994`

`Awkash Nagar, Chopan, Sonbhadra, Uttar Pradesh, India - 231205`

EDUCATIONAL QUALIFICATIONS

MASTER OF SCIENCE (M.S.) BY RESEARCH, `2016-Present`

Institution	:	National Institute of Technology Tiruchirappalli
University	:	National Institute of Technology Tiruchirappalli
Specialization	:	Electrical and Electronics Engineering
Grade	:	9/10

BACHELOR OF TECHNOLOGY (B.TECH.), `2010-2014`

Institution	:	BBD Northern India Institute of Technology, Lucknow
University	:	Uttar Pradesh Technical University, Lucknow
Specialization	:	Electrical and Electronics Engineering
Grade	:	First Division with Honours

RESEARCH INTERESTS

Smart Grids, Demand Response, Embedded Systems, and Internet of Things.

GENERAL TEST COMMITTEE

Chairman	**Name of the Chairman** Professor *Department of Electrical and Electronics Engineering* *National Institute of Technology Tiruchirappalli* Tamil Nadu, India – 620015.
Research Guide	**Name of the Guide** Associate Professor *Department of Electrical and Electronics Engineering* *National Institute of Technology Tiruchirappalli* Tamil Nadu, India – 620015.
Internal Member	**Name of Internal Member** Associate Professor *Department of Electrical and Electronics Engineering* *National Institute of Technology Tiruchirappalli* Tamil Nadu, India – 620015.
External Member	**Name of External Member** Associate Professor *Department of Electrical and Electronics Engineering* *Government College of Technology Coimbatore* Tamil Nadu, India – 641013.